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April 94

DOE ACCELERATOR ORDER 5480.25

IMPLEMENTATION PLAN

FOR

BROOKHAVEN NATIONAL LABORATORY

NATURAL PHENOMENA HAZARDS EVALUATION

Natural Phenomena Hazard Evaluation of BNL Accelerator Facilities

SUMMARY

The BNL Accelerator Facilities identified have been evaluated as mandated in DOE Order 5480.25 "Natural Phenomena Hazard, against the criteria of DOE Order 6430.1A "General Design Criteria" regarding wind, flood, and earthquake design criteria. DOE Order 5480.28 "Natural Phenomena Hazards Mitigation" and its associated standards were used as guidance for this evaluation.

The BNL accelerators and the buildings in which they are housed were built over a period of time ranging from 1949 to 1993. Design requirements over this period of time have changed considerably. Newer design criteria use a more precision engineering approach allowing the use of lighter materials as well as taking into consideration historical natural phenomena events. Older design criteria while being less precision was in fact more conservative in the design approach with buildings being built with more reserve strength. All BNL accelerator facilities were built to applicable codes and standards at the time of their construction.

All of the accelerators identified are considered Low Hazard Class and Performance Class 2. These facilities do not contain significant quantities of radioactive or chemical materials. Should a NPH event cause significant damage the impact would be mission related and not present a hazard to the public.

The meteorologic, hydrologic, geologic, seismological and geotechnical characteristics of BNL has been investigated and are sufficiently well understood.

The accelerator facilities were built under the supervision of BNL using the most current construction techniques and independent oversight to assure proper code compliance. All facilities at BNL are maintained by the Plant Engineering Division which has a full time staff of maintenance personnel. All maintenance and modifications are also to the most current codes. The Laboratory has numerous programs in place to identify any facility deficiencies as they arise so that prompt corrective action can be taken.

Because of the knowledge of how these facilities were built and maintained to national consensus codes, the low hazard classification and a low probability of a significant NPH event, BNL is confident that all of its accelerator facilities meet or exceed the requirements of DOE Order 5480.25. A more detailed investigation typical of Performance Category 3 and 4 facilities is not required nor would it be cost effective.

FACILITY DESCRIPTIONS

BNL has thirteen accelerators housed in ten facilities, that meet the requirements of DOE Order 5480.25 for an accelerator facility. Two of these accelerator facilities currently do not have an accelerator mission and two are idle accelerators, however they will be included in this evaluation should an accelerator mission be identified for them.

Alternating Gradient Synchrotron (AGS)

The AGS complex is used for high energy physics research which accelerates protons to energies of up to 30 GeV and heavy ions to 15 GeV/amu. This complex consists of the main AGS accelerator, a 200 MeV Linac and a Booster along with numerous experimental and ancillary buildings. Building 911 is the AGS Office-Service building: the original building was built in 1956 to provide support for the AGS program this building houses the main control room and support offices an addition of office space was made in 1965; consisting of a masonry exterior with a concrete frame; and housing three stories with a small basement. Building 912 is the main AGS Experimental Hall: which was built in 1958 and has had several subsequent additions as recent as 1988; consisting of a steel exterior and frame; and housing one story with a high-bay area. Building 913 is the AGS Tunnel: which was built in 1957; consisting of a steel and concrete exterior with a steel frame; housing one story underground, additions to the tunnel for shielding improvements were made in 1989 and 1990 significant structural analysis was performed at this time. Building 930 contains the 200 MeV LINAC which was built in 1969; consisting of a steel and concrete exterior with a steel frame; Building 942 houses the Booster facility which was built in 1987; consists of 10' corrugated steel tunneling with reinforced concrete transition points and flooring; Building 914 adjacent to the Booster tunnel houses the power supplies and associated equipment for the Booster. Building 914 was built in 1958 however underwent extensive modifications during Booster construction. Associated with this program are numerous ancillary single story buildings typically of steel exterior and frame construction, many of which would fall into a Performance Category 1.

National Synchrotron Light Source (NSLS)

The NSLS utilizes a linear accelerator and booster synchrotron as an injection system for two electron storage rings which operate at energies of 750 MeV vacuum ultraviolet (VUV) and 2.5 GeV (x-ray). The synchrotron radiation produced by the stored electrons is used for VUV spectroscopy and for x-ray diffraction studies. The building 725 structure houses the Synchrotron Light Source program: was built in 1981; consisting of a metal panel exterior with a steel frame; and housing two stories. In addition to the two energy rings and experimental floor this building houses numerous support offices, machine shops and laboratories.

Accelerator Test Facility (ATF)

The ATF is the flagship project of the Center for Accelerator Physics (CAP) to study advanced acceleration techniques and to carry out research involving free electron lasers and basic electrodymanics. This project makes use of a 50 MeV electron linear accelerator utilizing a radio frequency electron gun excited by a NdYag laser giving very short photon bunches to provide a very bright source of electrons with a total charge of 1 nanocoulomb. The ATF is under the administrative control of the NSLS Department. The ATF is housed in the west side of building 820, which was built in 1957; consisting of a steel exterior and frame; and housing a single story with a high-bay area.

Brookhaven Linac Isotope Producer (BLIP)

BLIP was the first proton spallation radionuclide production facility in the world, which has proven to be a valuable resource for the nuclear medicine community. This facility uses the excess beam capability of AGS's 200 MeV LINAC. The BLIP project is housed in building 931: which was built in 1971; consisting of a steel exterior and frame; and housing a single story.

Chemistry's 2 MeV Accelerator

The 2 MeV Accelerator is used as a pulsed electron source for pulse-radiolysis studies. These studies require short pulses of electrons to irradiate small liquid samples. The accelerator is located in a small permanently shielded room with one entrance on the ground floor of building 555. This building was built in 1966; consisting of a masonry exterior with a steel frame; and housing four stories above ground and one below.

40" & 60" Cyclotrons, Dynamitron & Small Van De Graff

The Dynamitron, 40" & 60" Cyclotrons, and Small Van De Graff are used in medium energy physics investigations, as well as for special nuclide production. Building 901 houses each of these programs. This building was built in 1949; consisting of a masonry exterior (panel and block) with a steel frame; and housing two stories above ground and one below. The Small Van De Graff's current operational status is "idle".

Tandem Van De Graaff

The Van De Graaff is also used in medium energy physics investigations, as well as for special nuclide production. The heavy ions from the Tandem Van De Graaff can also be injected into AGS for use in physics experiments. Building 901A houses the Tandem Van De Graaff and was built in 1968-69. This building is reinforced concrete construction partially embedded into a earth berm where it connects to an underground transfer tunnel leading to the AGS. Building 901A also connects to building 901 at ground level. Building 901A is one story with high bay experimental areas.

ELF 200 MeV LINAC

The ELF LINAC is a facility that was built to power the X-ray Lithography ring at the NSLS. This project lost funding after monies were committed for the purchase of the facility, therefore the LILAC is currently in shutdown mode. This facility is housed in building 729; which was built in 1993; consisting of a steel exterior and frame on a slab; and a single high-bay story. The ELF's current operational status is "idle". This facility was built in full compliance with DOE Order 6430.1A.

Radiation Effects Facility (REF)

The REF was built as a high-energy-proton source which allows users to evaluate particle beam/material interactions and TREE (Transient Radiation Effects on Electronics) responses in support of the Lethality-4 element of the SDI program. The REF utilizes the 200 MeV negative hydrogen ion beam produced at the LINAC injector to the AGS. This facility is housed in building 938; which was built in 1986; consisting of a steel exterior and frame; and one story above ground and one below. REF's current operational status is for non accelerator purposes (training facility). This facility was built in full compliance with DOE Order 6430.1A.

Neutral Beam Test Facility (NBTF)

The NBTF is facility fully integrated with the REF sharing beam from the AGS 200 MeV LINAC. The mission of this facility is to study the efficiency of focused accelerated neutral particle beams concentrating on the ability to aim and track. This facility is housed in building 939; which was built in 1986; consisting of a steel exterior and frame; and one story above ground and one below. NBTF's current operational status is for non accelerator purposes (High Temperature Combustion Facility). This facility was built in full compliance with DOE Order 6430.1A.

HAZARD CLASSIFICATION

Each accelerator facility has been evaluated and hazard classified as "Low" hazard facility as required by DOE Order 5480.25 and as defined in DOE Order 5481.1b. Hazard classification requests are included in each facilities implementation plan. A Low Hazard Classification is defined as "other than routinely accepted hazards, the activity only has hazards with the potential for no more than minor on-site and negligible off-site impacts to people or the environment".

PERFORMANCE CATEGORY

DOE Order 54880.25 requires that each facility be assigned a Performance Category as defined in DOE STD-1021-93 "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components". Since all the accelerator facilities are Low Hazard Class facilities, they fall in what is described in this Order as Performance Category 2 (PC-2), "Important or Low Hazard Facilities", (See Figure 2-1 pg. 5 from DOE STD 1021-93). Many of the support and ancillary buildings of the accelerator facilities fall into a Performance Category 1 (PC-1), "General Use Facilities".

The DOE Guidance Standard 1021-93 provides further guidance for classifying a facility as a PC-2; in addition to falling into a Low hazard classification the following criteria would also classify a facility as a PC-2:

"A Structure , Systems and Component (SSC) that does not satisfy the referenced safety system criteria may also be placed in PC-2 from cost and mission considerations, e.g., when SSC failure causes excessive downtime, SSC is very difficult to replace, or SSC replacement/repair is very costly".

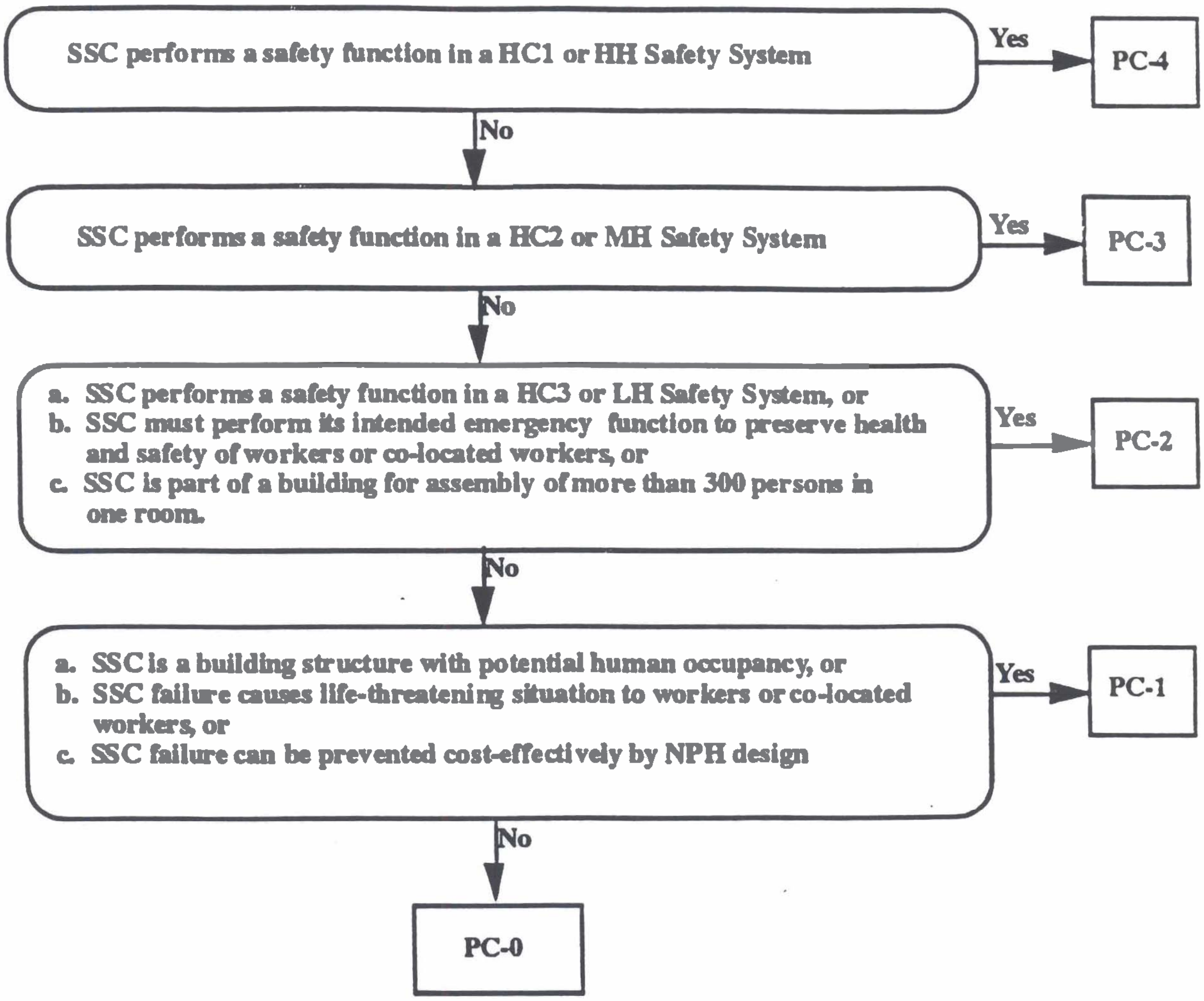
BNL accelerator facilities fall into the PC-2 classification due to both being low hazard class facilities as well as having a difficult and costly mission to replace. The BNL accelerator facilities identified have defined missions critical to the overall mission of the Laboratory. They have been characterized as a Low Hazard as per DOE Order 5481.1B, Guidance for an Accelerator Facility Safety Program. In addition to Standard 1021-93, UCRL-15910 considers "low hazard" facilities under 5481.1B to be considered "Important or Low Hazard Facilities" further defining them as "it is very important to maintain the capacity to function and to keep the facility operational in the event of natural phenomena hazards". This definition is somewhat restrictive for BNL accelerator operations as it was intended for hospitals, fire departments police departments etc. However, ANSI A58.1 is less restrictive in there requirements for this type of facility. Eventhough the mission of these facilities are important to the Laboratory some disruption of the operations could be tolerated should a NPH event occur and cause damage.

DESIGN CRITERIA

Construction of the BNL Accelerator Facilities was in accordance with the applicable codes and standards in effect at the time of their construction. (see table 1) The primary standards, are the Uniform Building Code, New York State Building Code, ANSI A58.1 and DOE Order 6430.1A. The ANSI Standard was originally issued in 1972 and subsequently updated in 1982. DOE Order 6430.1 was orginally issued in 12/83 with 6430.1A being issued in 12/87. The UBC would have been the principle code prior to 1972.

DOE Order 5480.25 considers PC-2 facilities built to building codes acceptable

Figure 2-1. Basic Guideline for Preliminary NPH Performance Categorization of Structures Systems, and Components



Notes:

SSC = Structure, System, or Component
HC = Hazard Category
HH = High Hazard Facility
MH = Moderate Hazard Facility
LH = Low Hazard Facility

Use this Figure only in the context of Section 2 of this document ; also see Subsection 2.5 for System Interaction Effects for natural phenomena concerns. UCRL 15910 states that facilities that are important or low hazard facilities (PC-2) are equivalent to essential facilities (class II), as defined in ANSI A58.1-1982 (see table 2). ANSI A58.1 states that "The structures main wind-force resisting structural systems shall not collapse at design wind speeds. Complete integrity of the building envelope is not required because no significant quantities of toxic or radioactive material are present". This is the case for BNL accelerator facilities.

Modifications of BNL facilities are also in conformance with applicable codes and standards. BNL maintains records of drawings, construction documentation and construction inspections for all of its facilities. However for this purposes of this assessment a detailed comparison of the drawings to actual configuration was not made and will not be made since none of the accelerator facilities exceed a Performance Category of 2, such a detailed analysis would not be cost effective.

DOE Standard 1022-92 "Natural Phenomena Hazards Site Characterization Criteria" allows sites containing only Performance Category 1 or 2 facilities to follow the procedures provided in model building codes or national consensus standards for the NPH assessment and the design evaluation. Although more detailed investigations are generally appropriate for facilities having higher performance categories then the BNL accelerator facilities, a great deal of current more detailed information of the potential Natural Phenomena Hazards possible at BNL is available and presented here. Much of this information was put together for the High Flux Beam Reactor and other Non-Reactor Nuclear Facilities and is further elaborated in the site Environmental Report.

Table 1. BNL Accelerator Facilities

FACILITY	YEAR BUILT/Bldg Number	HAZARD CLASS/PERFORMANCE CATEGORY	APPLICABLE CODE
AGS COMPLEX	1956-1988 / 911-930	LOW/PC2	UBC, ANSI, 6430.1A
NSLS	1981 / 725	LOW/PC2	UBC, ANSI
ATF	1957 / 820	LOW/PC2	UBC
BLIP	1971 / 931	LOW/PC2	UBC, ANSI
2 MeV	1966 / 555	LOW/PC2	UBC
40"&60" CYCLOTRONS, DYNAMITRON, SMALL VAN DE GRAAFF	1949 / 901	LOW/PC2	UBC
TANDEM VAN DE GRAAFF	1968-69 / 901A.	LOW/PC2	UBC
ELF 200 MeV	1993 / 729	LOW/PC2	UBC, ANSI, 6430.1A
REF	1986 / 938	LOW/PC2	UBC, ANSI, 6430.1A
NBTF	1986 / 939	LOW/PC2	UBC, ANSI, 6430.1A

Table 2* Classification of Buildings and Other Structures for Wind, Snow, and Earthquake loads	
Nature of Occupancy	**Category**
All buildings and structures except those listed below;	I
Buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area;	II
Buildings and structures designated as essential facilities, including , but not limited to: (1) Hospital and other medical facilities having surgery or emergency treatment areas. (2) Fire or rescue and police stations. (3) Primary communication facilities and disaster operation centers. (4) Power stations and other utilities required in an emergency. (5) Structures having critical national defense capabilities.	III
Buildings and structures that represent a low hazard to human life in the event of failure, such as agricultural buildings, certain temporary facilities, and minor storage facilities.	IV

* Table from ANSI A58.1 1982

METEOROLOGY

Regional Meteorology and Climatology

The general region is a combination of maritime and continental exposure, maritime along the coast gradually changing to more continental as one goes inland. On a broad scale the weather is greatly influenced by the Atlantic Ocean, Long Island Sound, and the various assorted bays. The presence of these water bodies and associated land units moderates both summer and winter temperatures, and strongly influences wind and humidity patterns. These factors also greatly reduce the snowfall in the BNL area from that expected as one proceeds inland to the more continental environment. The general area is well ventilated by winds of all directions with rapid, fairly consistent alternation among various types of atmospheric stability.

Local Climatology

In terms of meteorology, BNL can be characterized, like most eastern seaboard areas, as a well-ventilated site. The BNL site exposure is a cross between maritime and continental, being located within the gradual change in site exposure discussed in the previous section. The weather is greatly influenced by the Atlantic Ocean, Long Island Sound, and the various assorted bays and associated land units, also discussed above. However, the BNL site has one specific feature that is very characteristic of continental exposures, a pronounced tendency for excessive radiative heat loss during the night that results in minimum temperatures markedly lower than those at many nearby locations. The prevailing ground level winds are from the southwest during the summer, from the northwest during the winter, and about equally from these two directions during the spring and fall.

Temperature

The annual average temperature is approximately 49°F, which is higher than most places of the same latitude within the U.S. except along the Pacific Coast. Winter temperatures are milder because of the surrounding warmer water surfaces. During the summer, afternoon temperatures are moderated by local "sea breezes" blowing on-shore from the cool water surfaces. However, temperatures on-site have been recorded as high as 100.5°F in July to as low as -31°F in January. Monthly average temperatures are given in Table 3. The average temperature in 1991 was 52.9°F and the range was 21.2°F to 83.8°F. Monthly minimum, maximum, and average temperature data for 1991 are presented in Table 4.

Table 3

Monthly Average Temperatures (F) and Degree Days

	Mean	Maximum	Minimum	Total Degree Days
January	29.0	38.0	20.0	1114
February	30.0	39.3	20.8	986
March	36.5	45.8	27.2	884
April	46.0	57.3	34.8	570
	55.6	67.4	43.9	304
June	65.4	76.6	54.4	76
July	70.9	81.4	60.5	13
August	69.2	80.0	58.4	31
September	62.2	73.6	51.3	147
October	53.1	64.2	40.7	391
November	42.1	52.3	32.0	685
December	32.9	41.6	23.5	1007
Annual	9.4	59.8	39.0	6204

Table 4 Summary of Monthly Mean Climatology Data at BNL for 1991				
Month	Temperature F Min	 Max	 Ave	Precipitation cm
January	21.2	39.2	30.9	11.20
February	25.5	45.5	33.8	4.72
March	33.1	50.5	41.7	13.84
April	40.4	61.5	51.1	10.92
May	50.2	74.7	62.4	7.06
June	57	80	68.5	4.75
July	62.1	83.8	73	5.36
August	63	82.7	81.9	23.34
September	51.4	72.9	62.2	11.30
October	44.2	65.1	54.7	6.63
November	36	51.8	44.8	4.57
December	27.3	46.2	36.7	10.92
Annual	21.2	83.8	52.9	114.63
40 Yr Ave.			49.6	123.24

Note: Minimum and maximum temperatures listed for each month represent the lowest and highest temperature observed during the month.

Precipitation

The average annual precipitation is approximately 48 inches, with little variation in the monthly averages. Warm season precipitation is primarily convective, whereas most late fall and winter precipitation results from storms moving northeastward along or near the east coast. An hourly rainfall rate of > 2 inches and a 24-hr rainfall rate > 8 inches is exceptional but not unknown. Thundershowers have occurred during every month but most are prevalent during the summer. Because of the proximity of the ocean, storms are generated over inland areas around midday and are carried to eastern Long Island by upper-level wind flow, average relative humidity is 74% annually with a high of 82% during August and September, and a low of 66% in March.

Snow occurs between October and April. The seasonal amount averages 31 inches but varies greatly from year to year, e.g., 21 inches were recorded during 1965-66 and 75 inches during 1966-67. The mean annual number of days with freezing rain and/or freezing drizzle is 6. Heavy ice storms are infrequent and generally occur in January.

The total precipitation at BNL for 1991 was 45.3 inches, which is about 3.5 inches below the 40 year annual average. The historic (1949 to 1991) monthly precipitation data are presented in figure 2. The monthly and annual precipitation data for 1991 are also presented in Table 3. On the average, about half of the annual precipitation is lost to the atmosphere through evapotranspiration and the other half percolates through the soil to recharge ground water. Run offs form a very insignificant portion of the total rainfall, usually less than 2%.

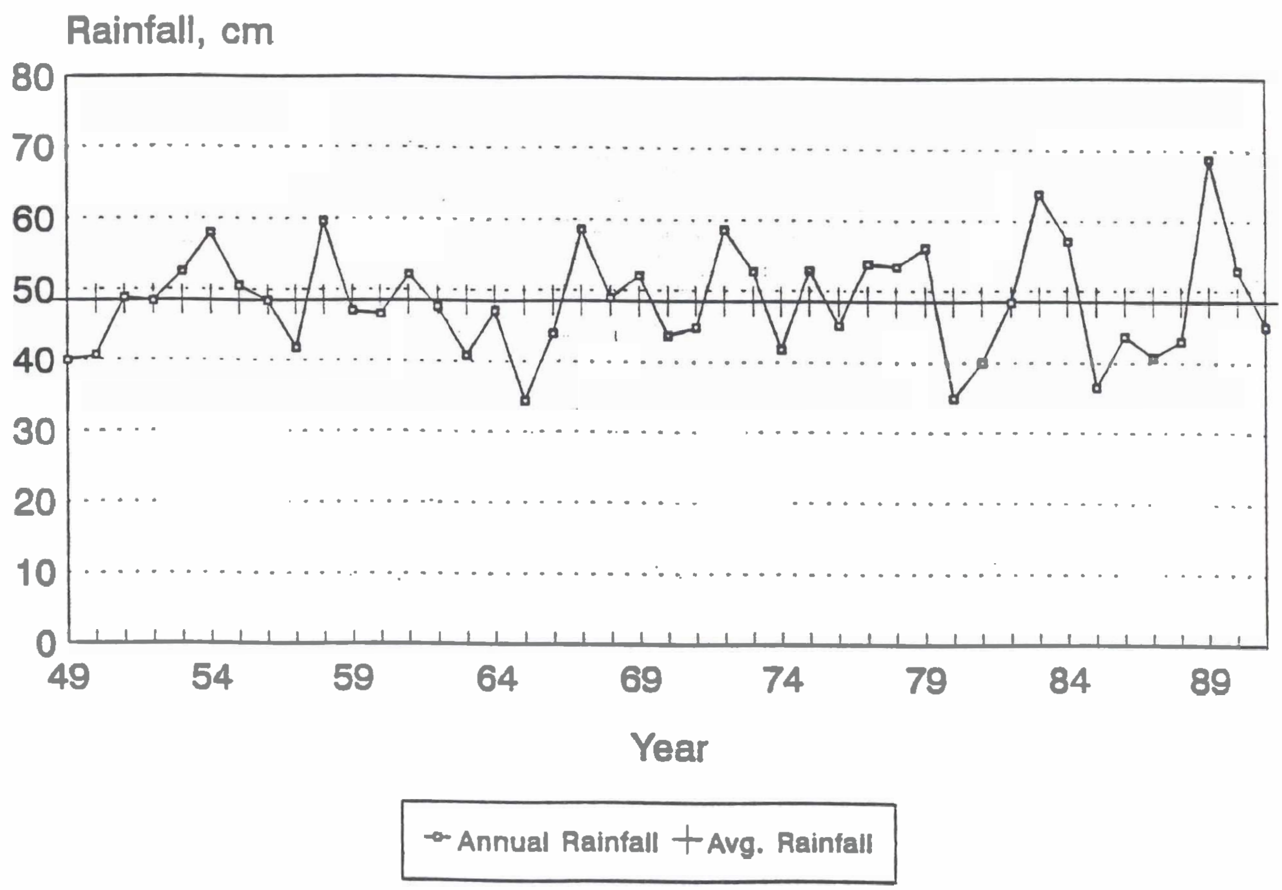


FIGURE 2. PRECIPITATION DATA FOR BNL, 1949-1991

Wind Occurrence

The highest wind speeds at BNL have occurred with hurricanes, e.g., an estimated 125 miles per hour during Hurricane Carol in September 1954. Hurricanes occur in June through October and a few weak or declining storms in May and November. In September chances are 92% for at least one tropical cyclone somewhere in the North Atlantic and 42% for three or more. The northeastern states were subject to hurricanes of moderate intensity only rarely between 1901 and 1931. Sections of the coast have been severely affected since 1932, with several hurricanes moving inland or passing close enough offshore to result in storms of hurricane winds, heavy rainfall, or high storm tides. However, tornados and hail storms are extremely rare on Long Island. The annual average tornado frequency is less than 1. The ten year average wind rose (1980 to 1989) for the BNL site is presented in Figure 3. The ANSI A58.1-1982 basic wind speed diagram is shown in figure 4. This figure shows Long Island falling between 80-90 mph.

Meteorological Extremes

Meteorological Extremes are listed in Table 5. The maximum precipitation values given for September 10-11, 1954 may be high since the rainfall sampler was somewhat disarranged by Hurricane Edna.

On-Site Meteorological Measurement

In August 1948, the BNL Meteorology Group set up its first complete observation station. Most of the data reported here were derived from standard meteorological equipment located at this facility. The equipment has been maintained in accordance with standard U.S. Weather Bureau procedures. In late 1993, a NEXRAD meteorological facility began operation at BNL, expanding the capacity of meteorological information gathering for the BNL area.

SURFACE HYDROLOGY

HYDROLOGY DESCRIPTION - REGIONAL & BNL SITE

Studies of Long Island hydrology and geology in the vicinity of the Laboratory indicate that the uppermost Pleistocene deposits, which are between 102 to 200 feet thick, are generally sandy and highly permeable. Water penetrates these deposits readily and there is little direct run-off into surface streams, except during periods of intense precipitation. On the average, about half of the annual precipitation is lost to the atmosphere through evapotranspiration and the other half percolates through the soil to recharge ground water. Run-offs form a very insignificant portion of the total rainfall, usually less than 2%. BNL lies on the western rim of the shallow Peconic River water shed. The marshy areas in the north and eastern sections of the site are a portion of the Peconic River headwaters. The Peconic River both recharges and receives water from the ground water aquifer depending on the hydrogeological potential. In times of drought the river water typically recharges to ground water while in times of normal to above normal precipitation, the river receives water from the aquifer. This area had been essentially dry from 1984 until the spring 1989. Consequently, liquid effluent from the BNL Sewage Treatment Plant (STP) constituted the principle source of water in the tributary's river bed during this period and the surface water recharged to the ground water prior to leaving the site boundary. Beginning in the second quarter of 1989 and continuing through 1990, heavy rains produced flow upstream of the BNL Chlorine House which provided sufficient additional volume along with a rise in the water table to produce flow off-site. In 1990, an estimated 0.21 million gallons per day of water was added to the headwaters of the Peconic River from ground water discharge. In early 1991, conditions similar to early 1989 were seen, and it was only after March 1991 that the combined ground water discharge plus BNL STP effluent flow was sufficient to produce a flow at the site boundary. The condition lasted until July 1991. From August through December 1991, the Peconic River bed on site was in a recharge mode. Consequently, no flow left the BNL site. The natural contour of the BNL site slopes from northeast to southeast. Figure 5 depicts BNL site drainage.

FIGURE 3. WIND ROSE FOR 1980-1989

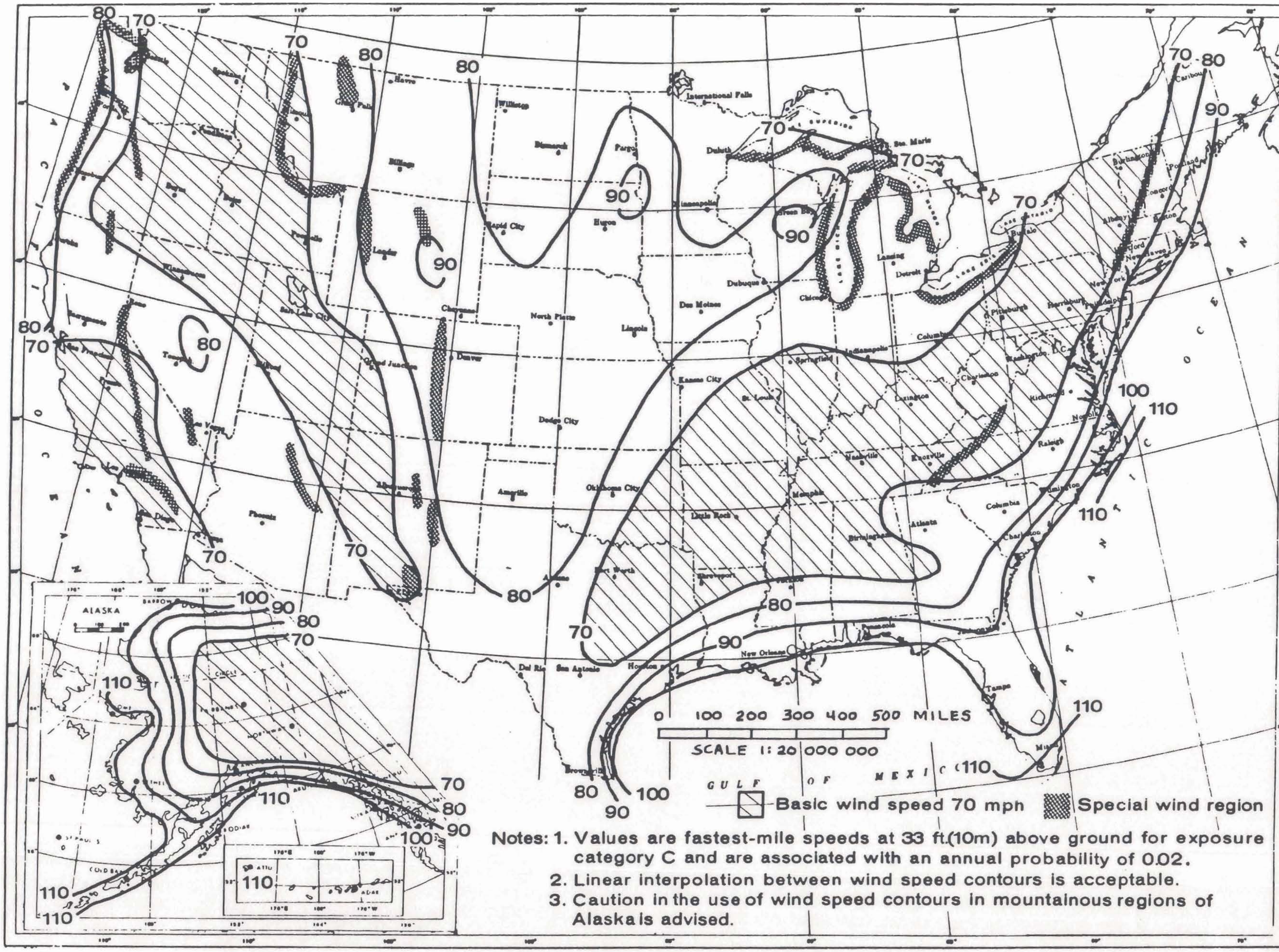


Fig. 4
Basic Wind Speed
(miles per hour)

Envirotranspiration of precipitation averages about 21 in/yr and represents the largest element of freshwater loss from the hydrologic system. Evapotranspiration from open bodies of water is negligible in terms of the overall water budget.

Most stream water (about 95%) is derived from the groundwater seepage. The balance that discharges into the sea is direct runoff. Practically all the precipitation not consumed by evapotranspiration, and not discharged into the sea, recharges the groundwater reservoir. The estimated recharge is about 23 in/yr, or about 820 Mgd for the Nassau-Suffolk area.

Table 5

Meteorological Extremes at BNL, 1947-1973

Observation	Record
Absolute highest temperature	100.5 F, 22 July 1957
Absolute lowest temperature	-32.0 F, 22 January 1961
Greatest daily temp. range	52
Least daily temp. range	2
Max. annual degree days (total)	6753, 1967
Max. monthly degree days	1342, January 1970
Max. annual precipitation	59.6 in., 1958
Min annual precipitation	34.35 in., 1965
Max. monthly precipitation	11.98 in. August 1954
Min. monthly precipitation	Trace June 1949
Max. daily precipitation	8.63 in., 11 September 1954
Max. total rainfall, single storm	9.02 in. 10-11 Sept 1954 (Hur. Edna)
Max. hourly rainfall	2.10 in. 11 Sept 1954 (Hur. Edna)
Max. seasonal snowfall	74.9 in., 1966-67
Max. monthly snowfall	32.0 in., February 1967
Max. daily snowfall	15.3 in., February 1958
Max. snowfall, single storm	19.0 in., December 1947
Longest continuous snow cover	55 days, 26 Dec 1947 to 18 Feb 1948
Absolute first day of snowfall	October 17
Absolute last day of snowfall	April 27
Peak wind speed	125 mph (est. at 410 ft) 31 Aug 1954 (Hur. Carol)
Lowest barometric pressure	28.375 in., 1450 EST, 12 Sept 1960 (Hur. Donna)

FLOODS

The only water course of any potential significance on the BNL site is the Peconic River, on the north-northeast side of the site. As discussed previously, the Peconic is frequently dry, and there is no record of the river producing any flooding that could encroach on the site. Therefore, flooding from surface water sources is not considered a concern.

As evidenced in BNL's "Site Environmental Report for Calendar Year 1993 (SER93)", there is a potential for the groundwater to rise to the surface in certain areas of BNL. According to this report, groundwater has risen to the ground surface at several locations on site. Groundwater is generally 35 to 40 feet below ground surface around the site and therefore not considered a flooding threat.

While BNL is relatively near the coast, there has been no Tsunami flooding of the area recorded. The effect of Tsunami flooding is not applicable. While there can be mild ice rain in the vicinity of BNL, it is not expected that the site will experience any severe ice jam, flood, wind driven ice ridges, or ice produced forces that would affect the facility.

WATER CANALS AND RESERVOIRS

There are no significant man-made water canals or reservoirs to pose any problems connected with their failure and so no applicable threats are posed to the site.

FLOODING PROTECTION REQUIREMENTS

Flooding is not considered a major threat to the site.

SUBSURFACE HYDROLOGY

Groundwater flow in the vicinity of BNL is controlled by many factors. The main groundwater divide lies about 1.25 to 5 miles south of Long Island Sound parallel to the Sound. This divide is known to shift 0.62 to 1.25 miles north to south (SER93). East of BNL is a secondary groundwater divide that defines the southern boundary of the area contributing groundwater to the Peconic River. The exact location of the triple-point intersection of these two divides is not known and may be under BNL. South of these divides the groundwater moves southward to the Great South Bay and to Moriches streams. In general, the groundwater from the area between the two branches of the divide moves out eastward to the Peconic River. North of the divide groundwater moves northward to Long Island Sound. Pressure of a higher water table to the west of the BNL area generally inhibits movement towards the west.

Variability in the direction of flow on the BNL site is a function of the hydraulic potential and is further complicated by the presence of clay deposits that accumulate perched water at several places plus the pumping/recharge of groundwater that are part of BNL daily operations. In general, groundwater in the northeast and northwest sections of the BNL site flow toward the Peconic River. On the western portion of BNL, groundwater flow tends to be toward the south to southeast. A site-wide water drainage map is shown in Figure 5.

In all areas of the BNL site, horizontal ground water velocity is estimated to range from 11.8 to 17.7 inches/day. The site occupied by BNL has been identified by the Long Island Regional Planning Board and Suffolk County as

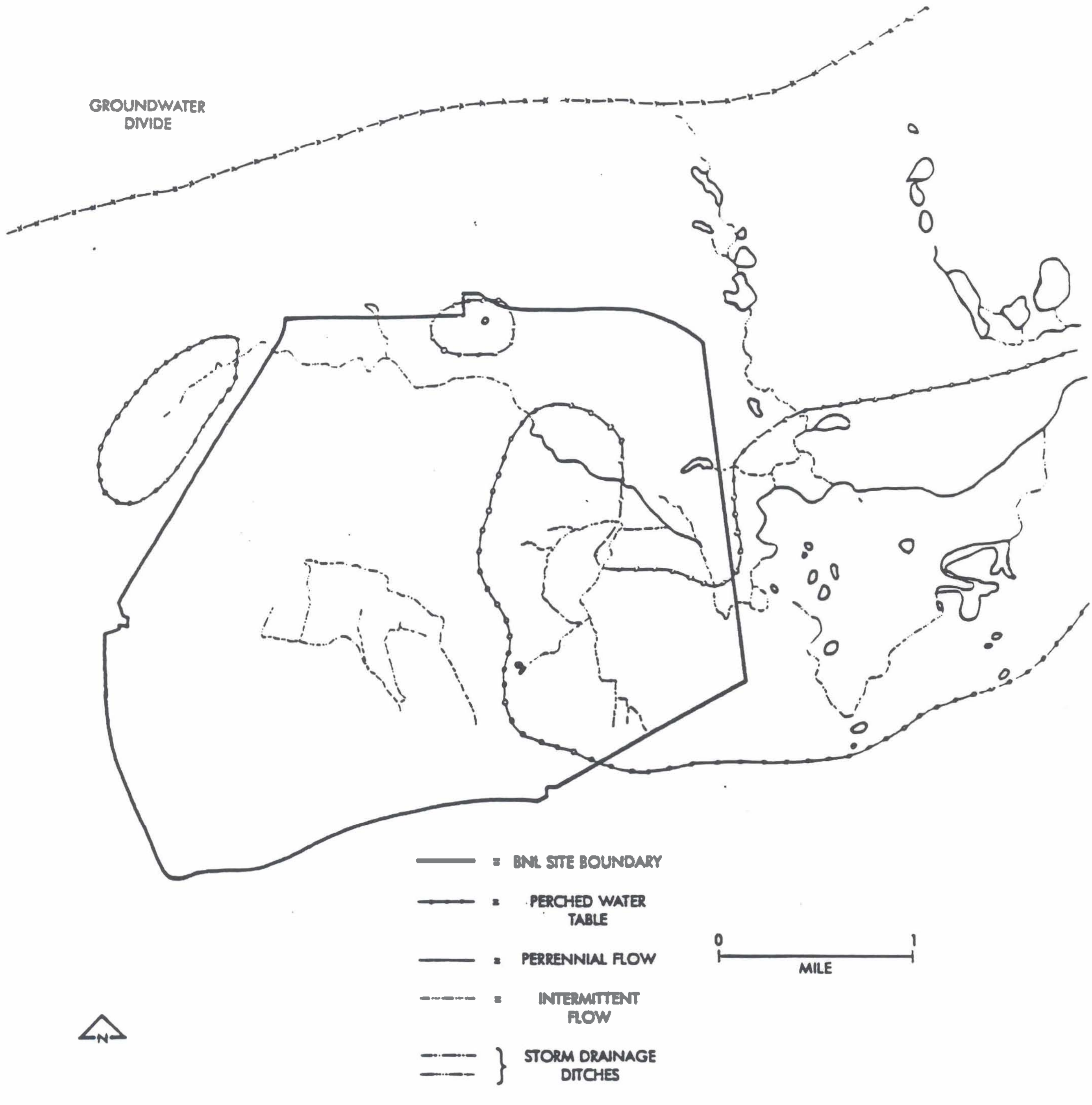


FIGURE 5 SITE DRAINAGE MAP

being over a deep recharge zone for Long Island. This implies that precipitation and surface water which recharges within this zone has the potential to replenish the lower aquifer systems (Magothy and/or Lloyd) which exist below the Upper Glacial Aquifer. The extent to which the BNL site contributes to deep flow recharge is currently under evaluation. However, it is estimated that up to two fifths of the recharge from rainfall moves into the deeper aquifers. These lower aquifers discharge to the Atlantic Ocean. Figure 6 is a map showing the approximate groundwater contours beneath BNL. Tables 6 and 7 present characteristics of the Long Island groundwater and clay formations.

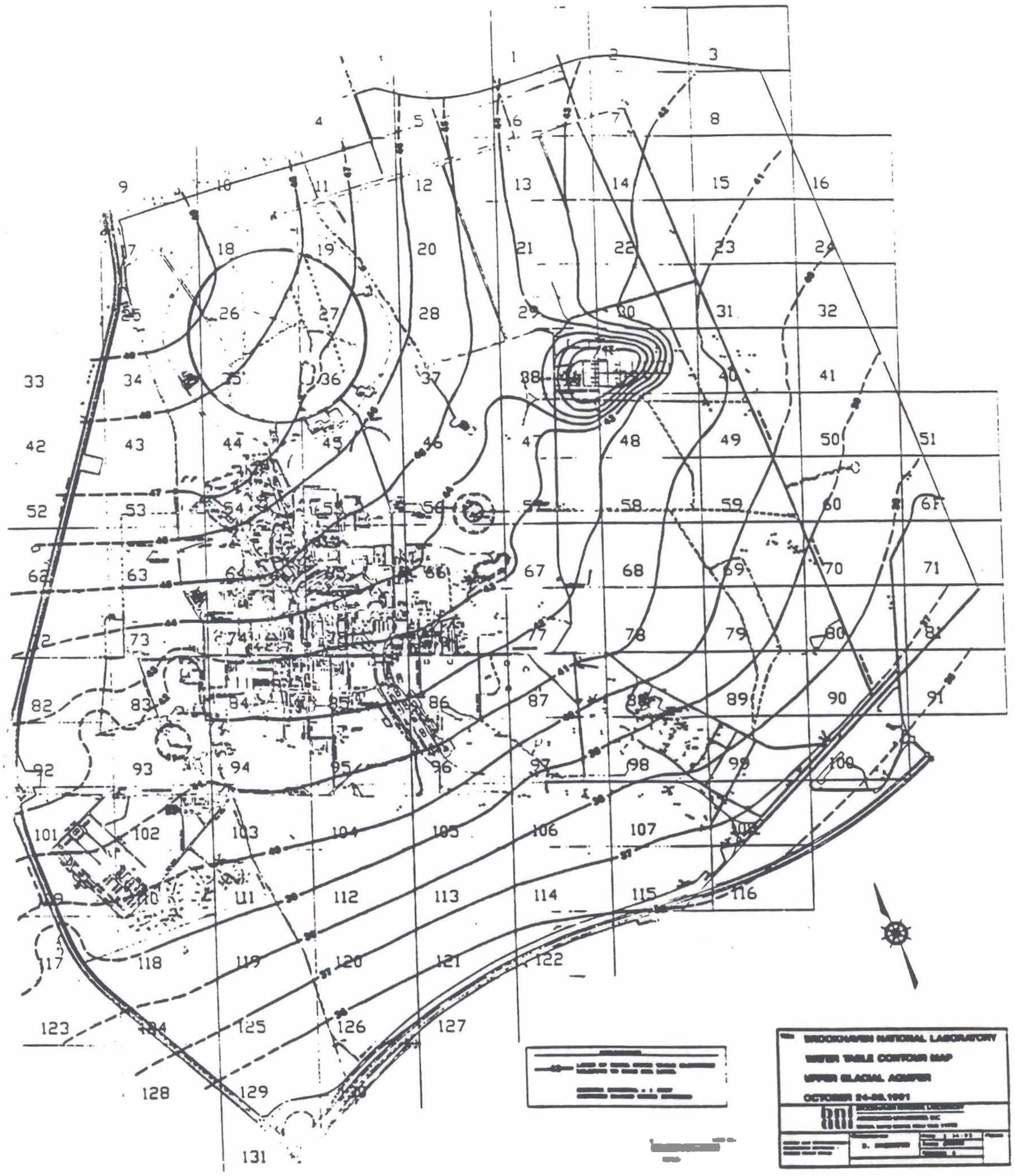


FIGURE 6 GROUND WATER CONTOURS

Table 6
Characteristics of Long Island Groundwater Reservoir

Hydrogeologic unit	Geologic name	Approx. max. thickness (ft)	Water-bearing character
Upper Glacial Aquifer	Upper Pleistocene Deposits	400	Mainly sand and gravel of moderate to high permeability; also clayey deposits of glacial till of low permeability.
Gardiners Clay	Gardiners Clay	150	Clay, silty clay, and little fine sand of low to very low permeability.
Jameco Aquifer	Jameco Gravel	200	Mainly medium to coarse sand of moderate to high permeability.
Magothy Aquifer	Magothy Formation	1000	Coarse to fine sand of moderate permeability; locally contains gravel of high permeability and abundant silt and clay of low to very low permeability.
Raritan Clay	Clay Member of Raritan Formation	300	Clay of very low permeability; some silt and fine sand of low permeability.
Loyd Aquifer	Lloyd and Member of Raritan Formation	300	Sand and gravel of moderate permebility; some clayey material of low permeability.

Table 7
AVERAGE CHARACTERISTICS OF AQUIFERS AND CLAY FORMATIONS AT BNL

	Pleistocene Deposits Below Water	Gardiners Clay	Magothy Formation	Raritan Formation	
				Clay	Lloyd Sand
THICKNESS (ft)	145	10	800	150-200	314
COEFFICIENT OF LATERAL PERMEABILITY (gpd/ft)	1,300	- ---	100-400	----	74
TRANSMISSIBILITY OF WHOLE FORMATION (gpdt/ft)	190,000	----	40,000	----	23,000
COEFFICIENT OF VERTICAL PERMEABILITY (gpd/ft)	103-350	0.3	----	-----	----
DIRECTION OF FLOW	SE	SE	SE	SE	SE
UNDISTURBED HORIZONTAL VELOCITY OF FLOW (ft/day)	0.5-1.0	----	0.25-0.1	----	0.005
HYDRAULIC GRADIENT	0.0010		0.0006		0.0002
POROSITY (%)	35		33		33

GEOLOGY AND SEISMOLOGY

BNL is located on Long Island which, as a whole, is terminal moraines of the last two glaciations. The Lab site is in the upper part of the Peconic River Valley, which is bordered by two lines of low hills. These extend east and west beyond the limits of the valley nearly the full length of Long Island and form its most prominent topographic features. The northern line of hills, known as Harbor Hill moraine, lies along the north shore, and the southern line, the Ronkonkoma moraine, extends along the center of Long Island and passes just south of the Laboratory.

Just west of the BNL site, the two moraines are connected by a narrow north-south ridge, for which the hamlet of Ridge is named. East of this ridge, and enclosed by it and two moraines, is the Manorville basin; the main laboratory grounds are on the basin's relatively high west margin. The basin forms the upper drainage area of the Peconic River. It is partly enclosed on the east, south of Calverton, by Bald Hill, an important feature of the Ronkonkoma moraine, so that the surface drainage of the Manorville basin is poor, and much of the land near the river is swampy. East of Calverton, the valley widens and forms the Riverhead basin.

West of the north-south ridge is the narrow, straight valley of the Carmans River, branches of which formerly drained Artist Lake and a pond at Middle Island. To the east, along the south margin of the Harbor Hill moraine, are two large kettle holes, Long Pond and Deep Pond.

South of the Ronkonkoma moraine is a comparatively flat featureless plain of irregular width. This surface slopes gently to the south, where it merges into a swamp and then passes under Great South Bay and Moriches Bay. The shoreline is indented by many small estuaries that are the drowned mouths of the small streams draining the plain. The principal irregularities of the plain south of BNL are the valleys of the Carmans River, which heads north of the moraine, and of the much shorter Forge River, which heads in the Ronkonkoma moraine just south and southeast of the Laboratory.

Between the mouths of the Carmans and Forge Rivers, the south shore bays are divided by a wide tongue of land extending nearly across to the Great South Beach, commonly called Fire Island Beach. To the east is Moriches Bay; to the west is the Great South Bay. The bays are bordered on the south by a long narrow line of barrier beaches.

The north shore of central Suffolk County is bordered by a long line of steep bluffs overlooking Long Island Sound. The line of bluffs is broken by several small embayments such as at Mount Sinai Harbor and Wading River.

Six principal stratigraphic units, some of which include subdivisions of minor importance, were recognized in the test drilling at the Laboratory. At the base is the oldest unit, the bedrock of Pre-Cretaceous age, which has been given no formational name. Above the bedrock is the Raritan formation of Cretaceous age, which is as much as 500 ft thick and has two members. The lower, as much as 300 ft thick, is called the Lloyd sand member and is composed of course-grained sand, gravel, and some clay. The upper, as much 200 ft thick, is mostly clay and is called the clay member. Overlying the Raritan formation is the Magothy formation, also of Cretaceous age. Beneath the Laboratory this formation consists of about 900 ft of mostly clayey sand, and it includes beds of clay and of sand and gravel. Under most of the Laboratory tract, and in general under the southern half of central Suffolk County, the Magothy formation is overlain unconformably by the Gardiners clay of Pleistocene age. The sixth major stratigraphic unit is called the upper Pleistocene deposits, an informal term for the glacial deposits which, in nearly all of Long Island, overlie the Gardiners clay of the Magothy formation. Most of these deposits consist of sand and gravel which, with local silt and clay, form the stratified outwash and morainal deposits of presumed Wisconsin age. Their maximum known thickness is about 200 ft. Most of the formations recognized here occur nearly everywhere beneath Long Island.

The bedrock underlying the unconsolidated deposits, as deep as 1,600 ft beneath BNL, includes hard dense schist, gneiss, and granite similar to that underlying much of the mainland in nearby parts of New York and Connecticut. These rocks were previously thought to be of Pre-Cambrian age, but now many geologist consider some of them to be metamorphosed early Paleozoic age sediments.

The shape of the upper surface of the bedrock of Long Island is best known beneath the west end. Here the bedrock surface, as indicated by well records, has a maximum relief of about 100 ft, except where it is near the surface and may have been modified by erosion in Pleistocene or recent times. The bedrock surface slopes southeast about 80 ft/mile under most of Long Island, but seems to have a more southerly slope at the east end. If the surface represents a peneplain, the relief on the bedrock surface in the BNL area is not likely to be greater than 50 to 100 ft.

SEISMOLOGY

The probability of occurrence in the BNL area of an earthquake sufficiently intense to damage buildings and reactor structures was thoroughly investigated during construction of the Graphite Reactor. It is the consensus of seismologists that no significant quakes are to be expected in the foreseeable future. No active earthquake-producing faults are known in the Long Island area.

Table 8 and 9 show that no earthquake has yet been recorded in the BNL area with an intensity in excess of III (1 to 8 cm/sec^2). However, since Long Island lies in a zone 2, (SEE FIGURE 7 from ANSI A58.1) moderate damage, seismic probability area, where it is assumed that an earthquake of intensity VII[1] could occur.

Table 8
EARTHQUAKES IN THE CENTRAL LONG ISLAND AREA*

		EPICENTER		
YEAR	DATE	LAT. (N)	LONG. (W)	INTENSITY** AT YAPHANK
1925	FEB. 25	47.6	70.1	I-III
1929	NOV. 18	44.5	55	I-III
1935	NOV. 1	46.8	79.1	I-III
1937	JULY 18	40.7	73.7	I-III
1944	SEPT. 5	45	74.8	I-III
1950	MARCH 29	41	73	I-III
1951	JAN. 25	UNCERTAIN	UNCERTAIN	NOT FELT

* AS REPORTED BY U.S. COAST AND GEODETIC SURVEY.
** MODIFIED MERCALLI INTENSITY SCALE OF 1931.

Zone 2 is considered moderate damage; corresponds to intensity VII of the Mercalli Intensity Scale.

Table 9 EARTHQUAKE INTENSITIES AND ACCELERATIONS*		
INTENSITY OF MODIFIED MERCALLI SCALE OF 1931	AV. MAXIMUM ACCELERATING ON ONE COMPONENT (CM/SEC)	RANGE OF ACCELERATIONS (CM/SEC)
II	2.3	1-5
III	3.1	1-8
IV	9.3	2-46
V	13.3	2-75
VI	40	5-175
VII	67	18-140
VIII	172.0	51-350
IX	250.0	250
*DATA FROM U.S. COAST AND GEODETIC SURVEY ACCELERAGRAPH RECORDS, 1930 TO 1941.		

STABILITY OF SUBSURFACE MATERIALS

As evidenced by the discussions in the preceding sections, the geology beneath BNL is stable. In addition, the chances of even a minor earthquake are remote.

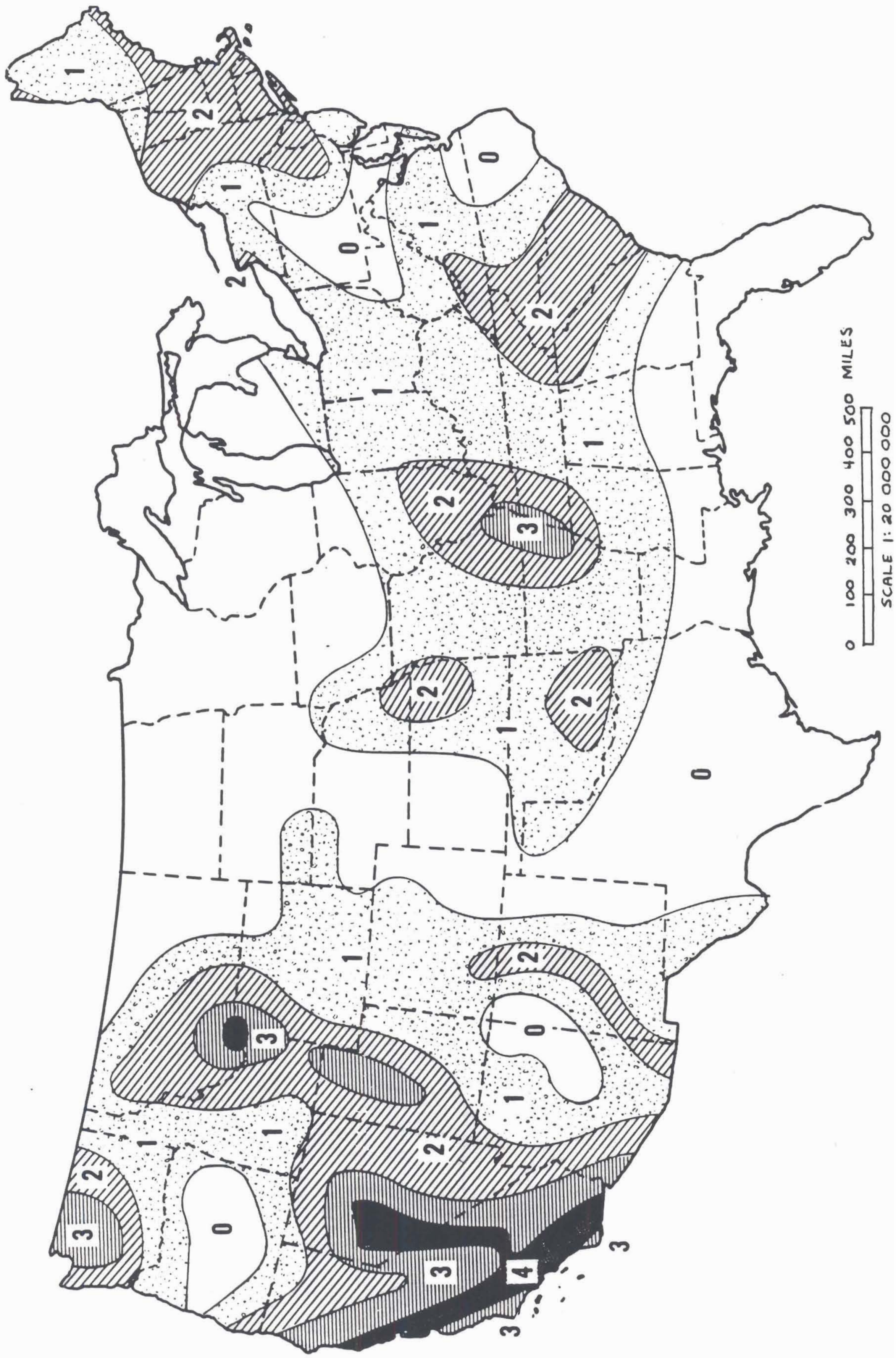


Fig. 7
Map for Seismic Zones – Contiguous 48 States

REFERENCES

1. United States Department of Energy, *Natural Phenomena Hazards Mitigation for Department of Energy Facilities,* DOE Order 5480.28, January 1993.

2. United States Department of Energy, *Safety of Accelerator Facilities*, DOE Order 5480.25, November 3, 1992.

3. United States Department of Energy, *Guidance For An Accelerator Facility Safety Program,* DOE 5480.25 Guidance, September 1, 1993.

4. United States Department of Energy, *Safety Analysis and Review System,* DOE Order 5481.1B, September, 1986.

5. United States Department of Energy, *DOE Standard, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components,* DOE-STD-1021-93, July, 1993.

6. United States Department of Energy, *DOE Standard, Natural Phenomena Hazards Site Characterization Criteria,* DOE-STD-1022-92, April 1, 1993.

7. United States Department of Energy, *DOE Standard, Natural Phenomena Hazards Assessment Criteria,* DOE-STD-1023-92, April 1, 1993.

8. American National Standards Institute, *Minimum Design Loads For Buildings and Other Structures,* ANSI A58.1-1982, 1988.

9. Brookhaven National Laboratory, *Site Environmental Report For Calendar Year 1991,* BNL 52347, September, 1992.

10. International Conference of Building Officials, *Uniform Building Code,* 1985.